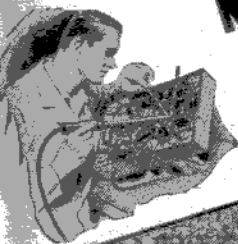


How to Make Extra Money **FIXING RADIOS**

NATIONAL RADIO INSTITUTE, WASHINGTON, D. C.

No. 22 **How To Fix a Receiver
That Hums**

RADIO SERVICING METHODS



NRI TRAINING PAYS...

Dear Mr. Smith:

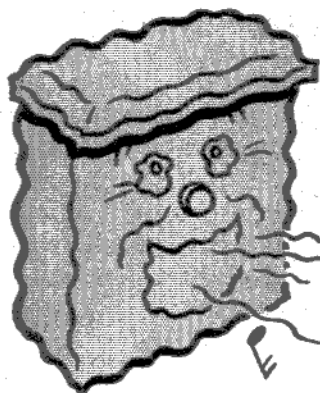
It was truly a turn in the right direction for me when I enrolled in your school. I started earning money after the tenth lesson. After graduation I carried on a successful spare time business. Then, because of my training, I was selected from many applicants for a position as a technician with a large electrical manufacturer. I am still employed by this company. The door to interesting work with good pay was opened to me through the training I received from NRI.

P.W., Illinois



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**NATIONAL RADIO INSTITUTE
WASHINGTON, D. C.**



HOW TO FIX A Receiver That **HUMS**

HUM is one radio defect that cannot be cured completely. It is always present to some extent in any receiver operating from a power line or from a vibrator power supply. Therefore, your aim in servicing a set with hum is to reduce the loudness of the hum to an unobjectionable level rather than to remove it altogether.

In this RSM Booklet, you are going to learn what causes excessive hum, and how it can be reduced. In addition, the practical experience section at the end of the Booklet will show you how to learn to recognize hum when you hear it. We shall deal primarily with receivers operated from a power line, because vibrator-operated receivers (auto sets and farm receivers) will be covered in another RSM Booklet. However, much of what we say can be applied to these receivers as well.

First, let's see what causes excessive hum. Fortunately, this defect has relatively few causes; once you have learned what they are, you will very often find it possible to locate the source of the hum without bothering with any elaborate localization procedures.

CAUSES OF HUM

Hum occurs when a low-frequency a.c. voltage gets into the signal circuits of a set. The two most common paths through which hum voltage enters the signal circuits are through a defective filter section of the power supply and through a leak between the cathode and the heater in a tube. There are also a few less common paths that we will take up later.

Since the hum voltage is an a.c. voltage, it can be amplified just like any other signal once it gets into the signal circuits. And, naturally, the more amplification it gets, the more noticeable it becomes. For example, a fairly large hum voltage could get into the power output stage without being very noticeable, but even a small hum voltage introduced at the input of the audio amplifier would receive enough amplification to be annoying by the time it reached the loudspeaker. Therefore, whether or not the hum voltage reaches an objectionable level depends to a great extent upon where it is introduced.

Now, let's study in detail the ways in which excessive hum can enter a signal circuit.

FILTER TROUBLES

At least 75% of hum complaints are caused by a defect in the power supply system. As you know, the filter is intended to smooth out the ripple voltage in the rectifier output to an acceptable level. It is this ripple voltage that causes hum. If the filter becomes defective, more hum or ripple voltage than normal will be applied to the tube elements in the set, and the hum level of the set will increase.

You have learned of the difficulties that may upset filtering, but let's review them briefly.

Fig. 1 shows two typical filter systems. An a.c.-d.c. set is shown in *A*, and a straight a.c. set in *B*, but the filter circuits could be used in either receiver. Condensers C_1 and C_2 are electrolytic condensers, connected with the polarities indicated.

Condenser C_1 is not likely to cause much hum. If this condenser loses capacity, develops a high power factor, or opens, there will be a slight increase in the a.c. ripple voltage, but the d.c. voltage will be dropped to such an extent that the receiver gain will be sharply reduced. Thus, although some hum may be heard, the chief complaint will probably be weak reception or a dead receiver. (If C_1 develops leakage or short-circuits, the rectifier tube will probably be ruined, and the result will be a dead receiver.)

► Most hum troubles are caused by condenser C_2 . When

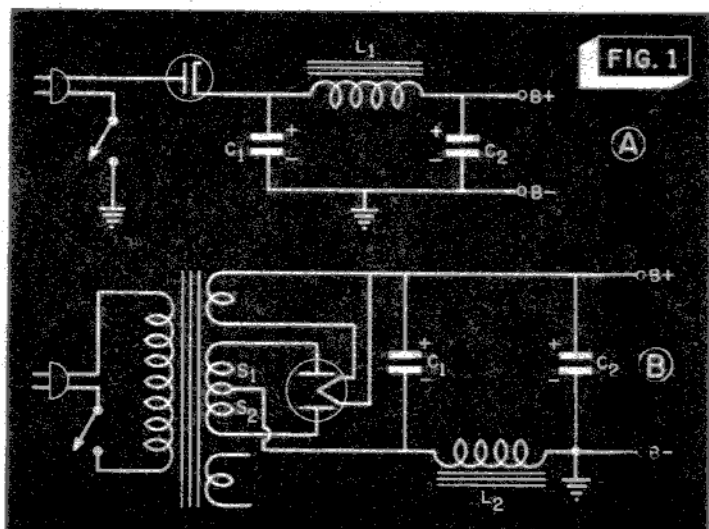
this condenser loses capacity or develops a high power factor, its ability to act as an a.c. voltage divider with the choke decreases, so a greater proportion of the ripple voltage is passed on to the tube electrodes. If C_2 opens, the hum will become very strong.

Leakage in condenser C_2 (or leakage in any condenser or circuit in parallel with C_2 at some point farther on in the receiver) will cause excessive d.c. current to flow through the choke. This will reduce the inductance of the choke coil, making it less effective as a filter component, and so causing greater hum. If C_2 shorts altogether, the set will become dead.

► Condenser C_1 and C_2 are frequently in the same condenser block. If leakage occurs *between* these condensers, there may be a shunting resistive path across the choke coil. Such a path will reduce the effectiveness of the choke and may cause hum. A similar shunting resistive path across the choke may exist in the circuit of Fig. 1B if leakage develops from the negative side of condenser C_1 to the chassis. This, too, may cause hum.

Of course, hum may also be caused by short-circuited turns in the choke coil, but such a defect is rare.

Unbalanced Full-Wave Rectifier Tubes. Hum is occasionally caused by unbalanced rectification in a full-wave power supply. In this case, the hum is a result of



the design of the filter. In a full-wave circuit like that shown in Fig. 1B, the filter is designed to remove the 120-cycle ripple that is normal for full-wave rectification. If anything happens to windings S_1 or S_2 of the transformer, or if one-half the tube becomes defective, the tube will still deliver d.c. because one of its plates will conduct current, but the frequency of the ripple will now be 60 cycles* instead of 120 cycles. This lower frequency is much harder to filter than is the 120-cycle ripple, and the filter system may not be capable of doing a good job on it. Therefore, there may be hum even though the filter is in good condition.

CATHODE-TO-HEATER LEAKAGE

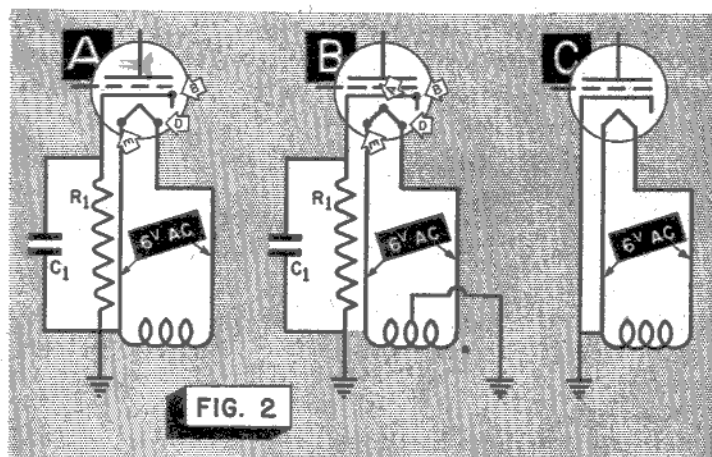
Most hum complaints that are not the result of filter troubles are caused by cathode-to-heater leakage in tubes. This is an odd trouble because it has to occur in a certain way before it can cause hum, and then may cause hum only in certain stages.

Fig. 2A shows the filament and cathode connections of a typical modern triode circuit. One side of the filament is grounded to the chassis, and the cathode is connected to the chassis through self-bias resistor R_1 , which is by-passed by C_1 . (As you know, any voltage existing between the cathode and ground is also between the grid and the cathode, so the voltage across R_1 is the d.c. bias voltage for the tube.)

However, let's suppose that some part of the cathode (marked B) shorts to the ungrounded end of the filament (marked D). This will create a path from D to the chassis through the cathode and resistor R_1 . This path and the filament are now in parallel, so some part of the a.c. voltage applied to the filament will also appear across R_1 . The exact amount across R_1 will depend on whether a complete short or just leakage exists between B and D.

Whether this a.c. voltage across R_1 causes hum depends on the capacity of C_1 . If this by-pass condenser has a high capacity, it may prevent any hum. However,

*This depends on the power-line frequency. If the power line is rated at 25 cycles, then full-wave rectification would produce a 50-cycle ripple.



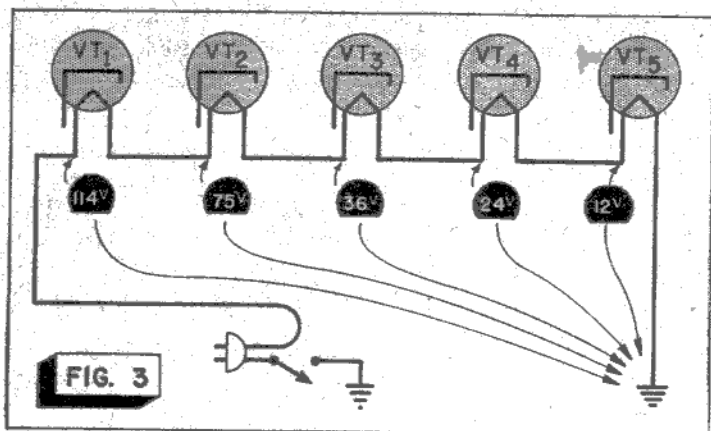
if the capacity is insufficient, or if there is a considerable amount of amplification between the grid circuit of this stage and the output, even a small amount of hum voltage developed across R_1 will be amplified sufficiently to cause hum.

On the other hand, if a short or a low resistance develops between B and E , there will be no hum because R_1 and the filament will not be in parallel, so there will be no a.c. voltage across R_1 . (However, the low-resistance path between B and ground will be in parallel with R_1 ; this may upset the bias and cause distortion or oscillation.)

If the filament connections are as shown in Fig. 2B, then a short circuit between B and either E or D may cause hum, but a short circuit between B and A will not, because the a.c. potential between A and ground is effectively zero.

► Finally, with the connection shown in Fig. 2C, no hum will develop regardless of how much cathode-to-heater leakage may exist, or to what points it occurs, because the cathode is directly grounded, and there is no way for the a.c. filament voltage to get between the grid and the cathode.

Therefore, cathode-to-heater leakage can exist in some stages without causing trouble and may have to exist in a special manner in other stages before it can cause trouble. (Even so, cathode-to-heater leakage is a



very common source of hum in radio receivers.) You can save time by examining the wiring diagram to see which stages may have this trouble—there is no need for checking the tubes in stages that cannot cause hum. ► The greater the voltage across the filament terminals of the tube, the greater the likelihood of hum, because then there will be a larger a.c. voltage placed across the bias resistor if leakage or a short develops. For this reason, cathode-to-heater leakage causes more trouble in a.c.-d.c. receivers than in a.c. sets. As shown in Fig. 3, the potential difference between the tube filaments and ground increases as one progresses down the filament string from the grounded end (as one moves from VT_5 toward VT_1). To compensate somewhat for this, set manufacturers arrange the tube filaments so that the *least* filament-to-ground voltage is applied to the tube that is most likely to cause trouble if it develops cathode-to-heater leakage. Then the next largest filament-to-ground voltage is applied to the second most troublesome tube, and so on.

Almost always, therefore, tube VT_5 is the first audio tube. Tube VT_4 may be the first detector-oscillator, VT_3 may be the i.f. tube, VT_2 the output tube, and VT_1 the rectifier tube. This odd order of connecting the tube filaments tends to minimize the possibility of hum.

Even though tube VT_2 is the power output tube, this arrangement of filaments results in such a high filament-to-ground voltage that leakage between its cathode

and filament may cause a considerable amount of hum. In fact, output tube leakage is the second most probable cause of hum in a.c.-d.c. sets. (A defective filter, of course, is the most probable cause.)

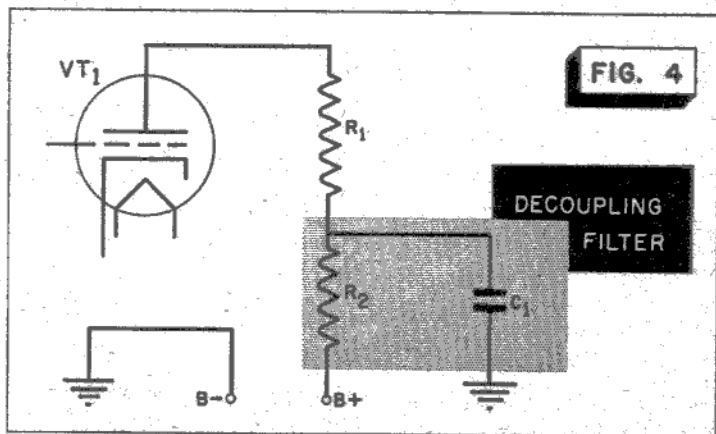
MISCELLANEOUS CAUSES OF HUM

Defective filter condensers, and cathode-to-heater leakage account for 90% of the hum troubles you will meet. The rest have unusual causes—the kind that baffle the radio mechanic but are readily found by a man with professional training.

One reasonably frequent cause of hum is a defect in a decoupling filter. In the filter shown in Fig. 4, C_1 and R_2 act as a voltage divider to reduce any hum voltage coming from the B supply. If condenser C_1 loses capacity or develops a high power factor (this condenser is frequently an electrolytic condenser), it will no longer act as an effective filter element, and hum voltage will be applied to the plate circuit of tube VT_1 .

Inductive and Capacitive Coupling. A.C. electromagnetic fields exist in and around the chassis of any power-line-operated radio receiver. These fields will cause no trouble in a well-designed receiver, but hum may result if anyone tampers with the position of critical leads or removes shielding.

Most trouble of this kind is caused by misplaced grid leads. Unless you notice where a repair has been made in which some critical lead may have been moved, you



will first have to use the methods described later to determine which stage the hum enters. Then you can try moving the leads in that stage with an insulated stick or alignment tool while the receiver is turned on. If you find a position where the hum disappears, you have solved the problem. Examine the set carefully to see if there is any evidence of shields missing. Also, if the control grid lead should be brought up inside a shield, be sure it is so placed.

Sometimes a receiver owner will tuck lengths of the a.c. power cord "out of the way" inside the radio. The strong a.c. field from this cord may induce hum in some grid circuit. Always pull the cord out to see if the hum decreases, then fold it or tie it up away from the chassis (but off the floor).

► Although less common than electromagnetic coupling, electrostatic induction also may cause hum. Electrostatic induction is the result of capacitive coupling between points. If stray coupling exists to a grid lead, for example, and the grid circuit contains a high resistance, then even a small electrostatically induced hum current will cause an appreciable voltage to develop across the resistance between the grid and the chassis. However, since stray capacities are small, only high-resistance grid circuits are much affected. In practically all cases where high resistances are used, the manufacturer minimizes this difficulty by keeping the tube grid leads short and placing them so that they are not easily disturbed. However, if anything happens to increase the resistance of the grid resistor, there may be appreciable hum induced in the circuit. Of course, any change in the grid resistor may also cause overloading of the tube or enough change in the bias so that distortion occurs. You may find that you have a combination complaint rather than a simple case of hum in such cases. This is often an aid in locating the defect, rather than an obstacle.

Hum Caused by Replacement Parts. Improper replacement of parts can sometimes cause hum. A typical example is a loudspeaker cone replacement. If the hum level is normal before the replacement but excessive afterwards, very likely the speaker has a hum-bucking

coil that has been improperly connected. This coil should be connected, as shown in Fig. 5, so that any hum voltages induced by the speaker field in both the voice coil and the hum-bucking coil will oppose and cancel each other. If the voice coil leads are connected backwards, the voltages will add, and hum will be increased. Unsoldering the voice coil leads and interchanging them will remedy this condition.

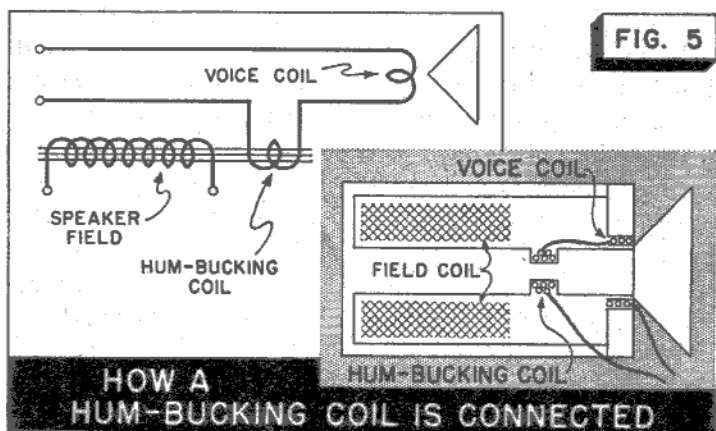
Sometimes a replacement choke or power transformer does not have the complete shielding of the original part. This may allow strong hum fields to escape from the part if it is a power transformer or choke, or to get into the part if it is an audio transformer. In such cases, it is best to get a more nearly exact duplicate if possible.

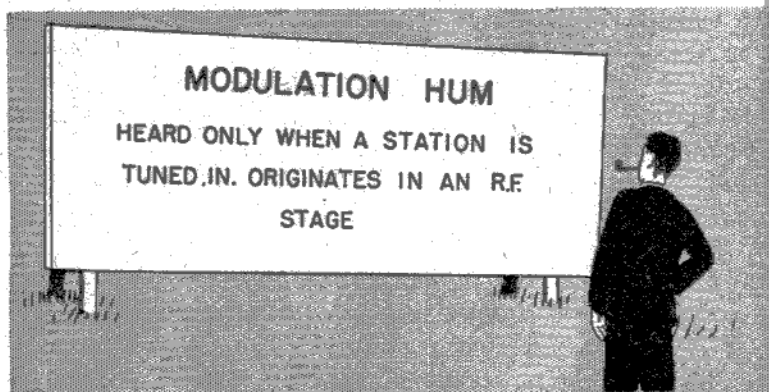
EFFECT-TO-CAUSE REASONING

Effect-to-cause reasoning is a very valuable aid in the case of hum. You can use it right away to localize the section where the hum originates.

As you know, hum is a low-frequency a.c. voltage. Therefore, the hum voltage picked up by an r.f. stage cannot pass through the tuned circuits unless it modulates the incoming signal. On the other hand, hum originating in the power supply or in the audio amplifier can be heard whether or not an r.f. signal is being received.

To locate the section in which the hum originates, then, just tune the set so that no station is picked up, and turn the volume control to minimum volume. If the



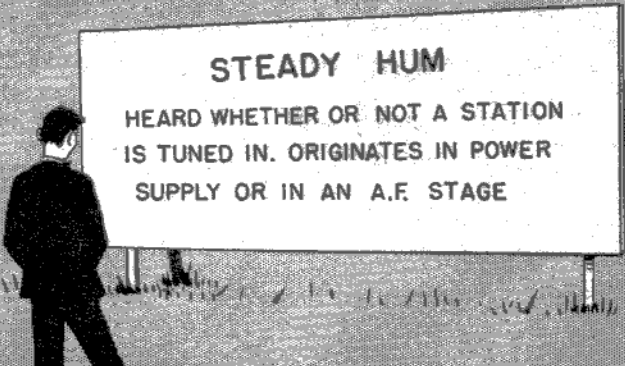


hum is still audible, it must be originating in the power supply or in the audio amplifier. If you hear no hum, turn the volume control back to a normal volume level, and tune the set to a station. If you hear hum now, it must be originating in an r.f. stage and modulating the incoming signals. A hum of this sort is called *modulation hum* or tunable hum. Thus, effect-to-cause reasoning plus simple tests will enable you to locate at once the section in which the hum originates.

► Effect-to-cause reasoning can be brought into use in some sets for a second time once you have learned to recognize hum frequencies. In practically all a.c. receivers that use power transformers, the rectifier tube is a *full-wave* rectifier. The fundamental frequency of the hum or ripple produced by this rectifier is twice the frequency of the line voltage. (For a 60-cycle line, this ripple is 120 cycles.) Therefore, if you hear a hum that has a fundamental frequency of 120 cycles, you know that the filter is not removing enough of the rectifier ripple.

On the other hand, hum caused by cathode-to-heater leakage, an unbalanced rectifier, or electrostatic or electromagnetic pickup from the power line will have the same fundamental frequency as the power line (60 cycles). Therefore, in a standard a.c.-operated receiver with a power transformer, 120-cycle hum indicates a filter defect, and 60-cycle hum indicates other troubles.

In a.c.-d.c. sets and others that use half-wave rectifiers, the fundamental hum frequency is the same as the power-line frequency, regardless of the defect.



STEADY HUM

HEARD WHETHER OR NOT A STATION
IS TUNED IN. ORIGINATES IN POWER
SUPPLY OR IN AN A.F. STAGE

BASIC TESTING

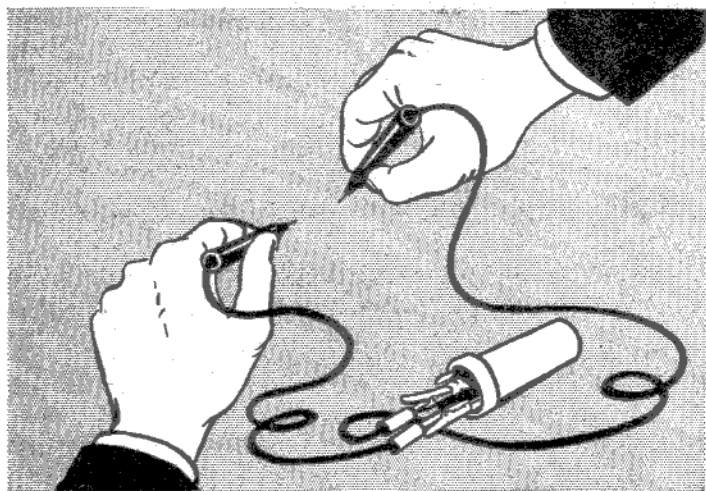
As we said, 90% of hum complaints (plain hum—not modulation hum) are caused by defective filter condensers or by cathode-to-heater leakage in an audio tube. Therefore, it is logical to check these suspects first, before making any further localization tests.

The simplest and quickest test for a suspected open or high power-factor electrolytic condenser is to try another one across it. Be sure that the test condenser has a working voltage rating at least as great as that of the condenser under test (450 volts or higher for a.c. receivers, 150 volts or higher for a.c.-d.c. receivers).

The capacity of the test condenser should be near that of the one across which it is connected, but this is not of extreme importance.

To make tests, first turn on the receiver (which must be connected to its speaker). If you can conveniently locate the output filter condenser, shunt your test condenser across it. Watch polarity—the positive terminal of your test condenser must go to the positive terminal of the original, and the two negative terminals also must go together. If it proves difficult to tell which is the output filter condenser, check each of the two or three electrolytic condensers, one at a time, with the test condenser.

If the hum clears up when you shunt the suspected condenser with the test unit, the condenser under test is defective and must be replaced.



The easiest way to connect a test electrolytic condenser across a filter condenser is to clip test leads to the terminals of the test condenser, as shown above, and touch the prods on the other ends of the leads to the terminals of the filter condenser. **CAUTION:** Be careful not to let your fingers touch the power supply circuits—you can get a severe shock.

► Frequently only partial hum reduction is observed when the output condenser is shunted with one of like capacity. This may mean the input condenser is also defective. If you wish, shunt both condensers simultaneously. Of course you can't hold all four leads at the same time, but you can temporarily solder in one test condenser and hold the other.

Make sure you test between the terminals of the original condenser. As we said in discussing Fig. 1B, the negative terminal of condenser C_1 is above ground potential. Therefore, you *cannot* consider that ground is one terminal of this condenser; to shunt it, you must locate both terminals of C_1 and connect your test condenser to them.

► If the hum is not greatly reduced when you shunt the test condenser across the output filter condenser, then the output filter condenser may be leaky. Shunting it with another will not be a test at all in this case. You must disconnect the original condenser and check it for leakage—either with an ohmmeter or by temporarily placing another condenser in the circuit in its stead.

Leakage between condensers is not easily checked except by disconnecting both condensers and trying others in their places. (An ohmmeter check is not reliable if the two have a common lead, because a check between the other two terminals will give you a reading whether or not leakage is present.)

If the capacity of the test condenser is far below that of the original condenser, the hum may not entirely disappear. However, any considerable reduction in hum shows that the original condenser should be replaced by one of the proper capacity.

► Cathode-to-heater leakage in a tube can easily be found by checking the tube for shorts or leakage in a tube tester. Be sure to check the rectifier tube to see that both halves have approximately the same emission, particularly if it is a full-wave rectifier and the receiver exhibits 60-cycle hum. In this latter case, also use an a.c. voltmeter to find out if the power transformer is delivering voltage to both plates of the rectifier.

Modulation hum is usually caused by the introduction of a hum voltage into an r.f. stage that has been forced off the straight portion of its characteristic. If such a stage is over-biased by some defect in the bias supply, for example, it will operate in a non-linear manner; this may permit even a fairly small hum voltage to cause modulation hum. Strong signals or a high hum voltage level may also cause the stage to operate off the straight portion of its characteristic. Cathode-to-heater leakage is the most usual way for the hum voltage to enter the stage.

LOCALIZING HUM

If you find that the trouble is not caused by a defective filter condenser or by cathode-to-heater leakage in a tube, it is best to determine where the hum enters the signal circuit. The procedure to use depends upon whether you have steady hum or a modulation hum.

Localizing Modulation Hum. Let's see how you could go about locating the stage in which hum modulation starts. Fig. 6, a typical a.c.-d.c. receiver, will serve as our example. At the start you know that the modula-

tion hum originates in the r.f. section—between the loop antenna and the volume control.

Either a signal tracer or the signal injection method may be used to locate the defective stage. If a signal tracer is used, it must be one of the kind with an audible output (one with a loudspeaker), because you want to *hear* the signal.

► If you have a signal tracer, first tune the receiver to a broadcast signal, and listen to the modulation hum to learn its characteristic sound. Then, turn down the receiver volume control so that it will be easier to hear the signal tracer output. Fasten the signal tracer ground lead to the set chassis. Touch the hot probe to the control grid of the 12SA7, and tune the signal tracer to the incoming signal. Listen to the tracer signal. If it has the modulation hum, the hum is coming in with the signal or is being modulated on the signal in the antenna or in the 12SA7 grid circuit.

If no hum is heard here, move the probe to the plate of the 12SA7. Hum now indicates trouble in the mixer or oscillator. If there is no hum, move to the grid of the 12SK7. By proceeding this way, you will eventually reach a point where the signal is modulated by the hum. The trouble will then be between that point and the last preceding point of test.

► A somewhat similar procedure is followed in the signal injection method. For this, you need a signal generator (abbreviated s.g.).

Set up the s.g. to give a modulated signal. Connect its ground lead to the receiver chassis. Place a .05 to .1 mfd. condenser in series with its hot lead (unless this condenser is built into your s.g.), and connect the hot lead to the control grid of the input tube (the 12SA7).

Next, tune the receiver to some point where a station is not picked up, and tune the s.g. to the same frequency. When the modulation tone of the s.g. is clearly heard, switch the s.g. to deliver an unmodulated signal and increase its output to maximum. The hum will be modulated on this signal and will be heard. Now tune the s.g. to 455 kc. (the i.f. frequency), and touch the hot s.g. probe to the plate of the 12SA7 tube. If the hum is no longer heard, the trouble is in the 12SA7 mixer or os-

cillator circuits. Check the tube, the continuity of the mixer control grid return circuit, and the oscillator grid resistor (if this latter has increased markedly in value, it may be causing self-modulation, which will sound like hum). Experiment with the position of the mixer and oscillator grid leads.

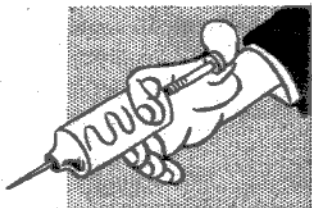
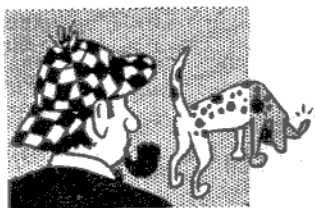
If the hum is still heard with the hot probe on the 12SA7 plate, move it to the plate of the 12SK7 tube. If the hum stops, the trouble is in the 12SK7 circuit; test the parts, the tube, and the wiring in it. If the hum continues with the hot probe on the 12SK7 plate, the trouble lies between this point and the volume control. Check the parts and the wiring involved. Also, try another 12SQ7 tube.

Localizing Steady Hum. Now suppose the hum is in the power supply or the a.f. section of the receiver shown in Fig. 6. First check the 20-mfd. and 12-mfd. sections of the filter, and test for cathode-to-heater leakage in the 12SQ7 and 35L6 tubes.

If this does not reveal the defect, an audio signal tracer, or the stage blocking procedure, can be used for localization. To use the signal tracer, first tune the receiver to a quiet point (no signals) so that the hum is all that is heard. Then, trace with the hot audio probe at the following points in order: grid of 12SQ7 triode, plate of 12SQ7 triode, grid of 35L6, plate of 35L6. When you first hear the hum coming from the signal tracer as well as from the set speaker, you have found the point where the hum is getting into the signal path.

► In the stage blocking method, the signal path is blocked at some point. If the hum is still heard, it is getting in between this point and the speaker. Otherwise it is getting in farther back toward the input. To use this method, proceed as follows:

Begin by shorting the *primary* of the output transformer with a test lead or a .5-mfd. condenser. (Connect the shorting lead or condenser *across the terminals of the primary.*) This prevents any signals from being fed from the 35L6 to the loudspeaker. If the hum is still heard, the hum-bucking coil (marked B.C.) is probably reversed, or else the power supply is defective. If the hum disappears when the output transformer primary



When steady hum is the complaint, you can use signal blocking or signal tracing, but *not* signal injection. For modulation hum, you can use signal tracing or signal injection, but *not* signal blocking.



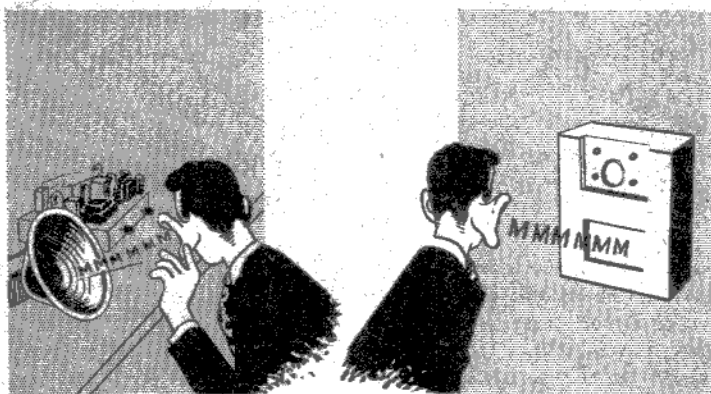
is shorted, remove the shorting lead (or condenser), and short across the 470,000-ohm 35L6 grid resistor. If hum is heard, it is originating in the 35L6 stage.

If you do not hear hum in this test, remove the shorting lead and short the 10-meg. grid resistor of the 12SQ7 tube. If hum is now heard, either it is originating in the 12SQ7 stage, or the grid of the 35L6 is picking it up.

If you don't get hum with the 10-meg. grid resistor shorted, remove the shorting lead, and turn the volume control to minimum volume. Any hum now heard is being picked up by the grid circuit of the 12SQ7. If turning the volume control up and down varies the strength of the hum signal, the control may be defective, or some of its wiring may be picking up hum from electromagnetic or electrostatic fields.

► This method of circuit blocking can be used on any type of receiver, a.c. or a.c.-d.c. However, in an a.c. set using a power transformer, it is often simpler to block signals by removing the tubes one at a time while the receiver is turned on. (Of course, this cannot be done with an a.c.-d.c. receiver.)

Thus, if you have an a.c. set, pull out the power output tube. If hum is still heard, investigate the hum-bucking coil and the power supply. If the hum stops, reinsert the tube into its socket and pull out the first audio tube. If you hear hum, it is getting into the power output stage or in the plate supply circuit of the first audio tube. If



Remember that hum will be louder when the set is in its cabinet than when it is on your bench. This is especially true when the set has a console cabinet, which usually reinforces low notes considerably. Always check the hum level with the set in its cabinet before delivering it to the customer.

no hum is heard with the first audio tube removed, the trouble is probably cathode-to-heater leakage in this tube or is an open grid circuit.

Points to Remember. Any a.c.-operated receiver will have a certain amount of hum that cannot be eliminated. If you listen carefully, you can hear this hum from practically any receiver. We suggest you listen to a number of receivers that are in good condition to become familiar with the amount of hum that is considered acceptable to the average radio listener.

Hum is always more pronounced when the loudspeaker is in its cabinet, for the cabinet improves the response to low-frequency notes. Sometimes, when a receiver (and loudspeaker) is on the workbench, it is almost impossible to hear hum that would be objectionable with the chassis and speaker mounted in the cabinet. You can get an idea of the intensity of the hum with the set out of the cabinet by tuning away from a station and barely touching the speaker cone with the end of your finger. If hum is present, you will feel a vibration of the speaker cone. Whenever you service a set for hum, be sure to notice the loudness of the hum with the chassis in and out of the cabinet. This will give you a good idea of how much difference the cabinet makes.

NRI PRACTICAL TRAINING PLAN

Hum is one of the easiest of the service complaints to introduce into a radio receiver. Carry out the following suggestions on the set that you are using for the NRI Practical Training Plan. This should be a standard a.c. receiver with a power transformer and a full-wave rectifier.

To learn the difference between 60-cycle and 120-cycle hum, locate the output filter condenser, and temporarily unsolder it from the circuit. When you do this, there will be a strong hum from the loudspeaker. If everything else is normal, this hum will have a 120-cycle fundamental frequency plus higher harmonics.

When you think you can recognize this hum, resolder the filter condenser and introduce a 60-cycle hum. There are several ways of doing this; one of the best is to connect a small condenser (.01 to .05 mfd.) from the ungrounded side of a filament to the control grid of the first audio tube. This will introduce a strong hum with a 60-cycle fundamental frequency and higher harmonics.

Much depends on the response characteristics of the receiver as to whether you can at once tell the difference between these two hum frequencies. If the set does not respond very well to low frequencies, you may hear only the higher harmonics of the two, which would sound much alike. Listen to the two hum frequencies carefully, one after the other, until you think you can recognize the difference between them.

Now proceed to introduce various defects. The test we have just described (opening the output filter condenser) has the same effect as a loss of capacity would have. Make the same test on the input filter condenser by reconnecting the output condenser and disconnecting the input condenser. The hum level will increase, but the d.c. voltages will all drop radically, and you may have weak reception or even a dead receiver. Try out the set to see how it works with the input filter condenser disconnected.

High power factor in either electrolytic condenser will have the same effect as opening the condenser, so there is no necessity for demonstrating this condition. Leak-

age is important only when it occurs in the output filter condenser. You can simulate leakage by connecting a 5000-ohm 10-watt resistor in parallel with the output filter condenser so that it draws extra current through the filter choke. This will probably increase the hum, but it will cause a lower-than-normal plate voltage on most of the tubes, and this may prevent the hum level from becoming much more noticeable.

► Cathode-to-heater leakage can be simulated by connecting a resistor of about 5000 ohms between the cathode terminal of a tube and an ungrounded filament terminal on that tube socket. This will not cause hum in certain stages, but in others there will be a strong hum. Try this on audio stages in which the cathode is not directly grounded—that is, stages that have bias resistors. Try it in r.f. and i.f. stages as well, and see if you can cause modulation hum.

► You can take off tube shields and introduce other conditions we have described earlier in this RSM Booklet, to see just what effect they have in your receiver. Try bringing the power cord close to the grid lead of the first audio tube. Finally, create excessive hum in your set while the speaker is in its cabinet, then remove it from the cabinet, and notice the hum level. Compare this level with the first one to learn how different the hum level may be when the set is on the workbench. Lightly touch the cone with your fingers to feel the vibration caused by the hum (no signals should be tuned in), then cure the hum and feel the cone again. You can frequently feel the difference as well as hear it.

THE N. R. I. COURSE PREPARES YOU TO BECOME A RADIOTRICIAN & TELETRICIAN (REGISTERED U.S. PATENT OFFICE)

COMMON CAUSES OF HUM

SEVERE

<i>Cause</i>	<i>How to Test</i>	<i>Usual Location</i>
Open or high p.f. output filter condenser	Shunt with a good condenser	Power supply
Leaky output filter condenser	Replace with a good condenser	Power supply
Cathode-to-heater leakage	Test tube	Audio section
Leakage through case of condenser	Disconnect ground strap from chassis	Power supply

ANNOYING

Open or high p.f. input filter condenser	Shunt with a good condenser	Power supply
Half of rectifier tube defective	Test tube	Power supply
Power cord near audio tube grid	Visual examination	Audio section
Hum-bucking coil reversed	Reverse connections	Speaker